N86-71164

NASA TECHNICAL MEMORANDUM NASA TM-77989

STUDY OF THE DEFORMATION OF CER-VIT IN RESPONSE TO ELECTRONIC IRRADIATION

J. Bourrieau and M. Romero

Translation of "Etude de la deformation du CER-VIT sous irradiation électronique," Centre d'Etudes et de Recherches de Toulouse, Département d'Etudes et de Recherches en Technologie Spatiale. IN: Conference on Space Optics, 4th, Marseille, France, November 6-8, 1973, pp. 385-397

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 SEPTEMBER 1974

STANDARD TITLE PAGE

1. Report No.
NASA TM-77989

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
STUDY OF THE DEFORMATION OF CER-VIT IN REPONSE TO ELECTRONIC IRRADIATION

5. Report Date
September 1974

6. Performing Organization Code

7. Author(s) J. Bourrieau and M. Romero, Toulouse Study and Research Center, Department of Space Technology Study and Research

8. Performing Organization Report No.

10. Work Unit No.

9. Performing Organization Name and Address
Leo Kanner Associates
Redwood City, California 94063

11. Contract or Grant No.
NASw-2481

13. Type of Report and Period Covered
Translation

12. Sponsoring Agency Name and Address
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

soring Agency Code

15. Supplementary Notes
Translation of "Etude de la deformation du CER-VIT sous irradiation électronique," Centre d'Etudes et de Recherches de Toulouse, Département d'Etudes et de Recherches en Technologie Spatiale. IN: Conference on Space Optics, 4th, Marseille, France, November 6-8, 1973, pp. 385-397 (A74-28143)

16. Abstract Laboratory simulation of the damage resulting from exposure to ionizing radiation is very difficult to achieve. The methods used for these tests on optical components sent into space are discussed briefly, followed by the study of a specific material, CER-VIT, which is used as a substrate for mirrors or gratings. The deformation caused by radiation is described, as is the influence of the different parameters (temperature, radiation energy and dose rate), which may vary depending on the mission. The electronic irradiation results for the primary mirror of the Meteosat are given.

17. Key Words (Selected by Author(s))

18. Distribution Statement
Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	16	

NASA-HQ

STUDY OF THE DEFORMATION OF CER-VIT IN RESPONSE TO ELECTRONIC IRRADIATION

J. Bourrieau and M. Romero
Toulouse Study and Research Center
Department of Space Technology Study and Research

I. Introduction

When a material -- a component -- is sent into space, during passage through the magnetosphere it is exposed to radiation which may alter it. Thus an attempt must first be made to determine that it is satisfactorily resistant to irradiation on the ground. /*

This apparently simple reasoning actually raises a complex question, that of the procedure which should be used to obtain maximum certainty as to the validity of the simulation.

The irradiation actually undergone by the satellite in space has the following characteristics:

-- several types of radiation (electrons, protons, UV, etc.) are received simultaneously, each of these being multi-energetic and omnidirectional;

-- flux levels are low;

-- temperature conditions are established by the satellite;

-- the ambient medium is a vacuum, or, worse, residues from degassing.

---

*Slash marks in the margin indicate a new page in the foreign text.

At the present time it is impossible to obtain all these conditions in the laboratory, either for reasons of time (missions lasting for a period on the order of a year, thus making it necessary to increase the flux level by a factor of 10^3 to 10^5 for simulation), material (the difficulty of simultaneously producing different types of radiation, and the frequent impossibility of keeping to their intensity ratios and their energy spectra) and cost.

The simplest type of laboratory irradiation is obtained with accelerators, and thus with monodirectional and mono-energetic radiation with a relatively high flux level.

Some of the previously described conditions may be obtained, for example:

-- low flux level and proper energy spectrum, by using a Sr^{90} source which is useful for reproducing the background noise produced by electrons in the detectors;

-- the multidirectional aspect, with the use of an appropriate rotating device;

-- simultaneity of several types of irradiation;

-- in situ measurements, preventing possible recovery upon exposure to the air.

Nevertheless the simulation will not be perfect, since it will not reproduce the space environment exactly. Consequently, in order to choose the parameters which will define the most representative whole (that is, which will produce degradation analogous to that occurring in space) and if possible, the least costly conditions, it is necessary to have a fairly accurate idea of the influence of the factors which are overlooked, and thus, finally, the physical phenomena which may be brought into play.

The problem of simulation occurs in two types of situations.

The first is the situation when the mission has been defined, the shape of the satellite determined, and a material or component selected. The experiment to be performed consists in testing the strength of this material or component under well-defined conditions; it includes the following preliminary steps:

-- calculation of the environmental flux of protons, electrons, etc. [1];

-- calculation of the environment inside the space vehicle [2];

-- analysis of the type of degradation which may be predicted;

-- if necessary, the performance of small adjustments to ascertain that the parameters assumed to be negligible actually are negligible;

prior to the irradiation per se.

The second situation is that of testing a material, independent of the mission defined, or comparison of this material with other materials.

The series of steps is summarized in Table 1.

The following discussion will show how a specific case has been handled: the problem of the CER-VIT mirror of the Meteosat.

2. Study of CER-VIT

2.1. Analysis of Problem

Since irradiation of CER-VIT support gratings showed that this material degraded, the problem of the Meteosat mirror arose. The problem was analyzed in the following manner:

-- The degradation to be studied is significant only if it occurs in depth; the radiation to be used therefore consists of electrons with energy on the order of a MeV; /

-- No synergic effects may be expected, since the photons are unable to reach the protectively coated material when it is used as a mount for the mirror, and protons do not penetrate to a sufficient depth.

These are the positive points, to which one might add the following reasoning, which moreover is a simple assumption:

-- The optical properties are of no importance, and only deformation is a problem. This deformation can only be related the displacement of atoms, which in covalent crystals is generally produced only by impacts; it is logical to assume that few secondary processes will be brought into play, and thus the irradiation may be expected to remain simple.

However, this is only an assumption at this stage of the study, and the negative points are as follows:

-- The influence of the energy, the dose rate and the temperature are unknown;

-- It is impossible to perform the entire series of tests on a full-size structure analogous to the actual mirror (40 cm in diameter).

It was therefore decided to perform a preliminary study on the material itself, independent of the form it will be used to coat, in order to assess the influence of the various irradiation parameters and to figure its degradation.

2.2. Degradation of CER-VIT in Response to Electronic Irradiation

The samples used for the tests were disks 40 mm in diameter and 8 mm thick.

During the irradiation they were placed on a cooled holder.

The deformation was measured by photographically recording the interference fringes formed within the wedge of air created between the irradiated sample and a control (Fig. 1). The light source was a 6328 Å laser.

In addition, variations in the system of fringes as a function of the storage time after irradiation were monitored at various temperatures in order to determine and accelerate possible recovery processes.

2.2.1. Depth of Coloration

The darkening of the irradiated area made it possible to measure its depth, which varied as a function of the energy of the incident electrons; here this was 0.47 MeV, 0.87 MeV and 1.37 MeV.

This thickness was also calculated by means of a program [2], taking multiple scattering into account.

The results are summarized in Table 2.

2.2.2. Degradation Curves at Various Energy Levels

The deformation was parabolic in shape for completely irradiated CER-VIT blocks (Fig. 2). Fig. 3 shows the amplitude of the deformation as a function of the flux received at various electron energy levels (1.37, 0.87 and 0.47 MeV) and at a fixed flux level ($5 \cdot 10^{11}$ $e^-/cm^{-2}/sec^{-1}$).

This deformation actually consisted in the appearance of a concavity, which was controlled by determining the direction of displacement of the fringes and by using a microscope with a short depth of field. The material contracted in response to electron irradiation; this behavior may be compared with that of vitreous silica, whose density increases under irradiation [3].

The deformation increases with the energy of the incident particles. It reaches an amplitude in the vicinity of 3 μm for 10^{16} electrons of 1.37 MeV per cm^2, and is negligible for electrons of less than 0.5 MeV.

2.2.3. Influence of Flux Level

The irradiation was performed with a flux level of $7 \cdot 10^{10}$ $e^-/cm^2/sec$ and an energy level of 1.37 MeV; the results were comparable to those previously obtained. The factor of 10 on the flux level did not produce any difference in the amplitude of the degradation.

2.2.4. Influence of Annealing

Several samples stored at the ambient temperature for three weeks were measured at increasing time intervals. No variations were observed.

The recovery which usually occurs when irradiated glass is heated to high temperatures was also obtained with CER-VIT (Fig. 4). The decrease in deformation occurred in conjunction with a disappearance of color from the material, which, after 4 hrs at 450°C, returned to its initial condition.

2.2.5. Interpretation of Results

Deformation was observed, since the upper part of the disk contracted in response to irradiation, while the lower part remained unaffected.

In order to assess the order of magnitude of the deformation coefficient, the method chosen was to put the block in the form of a bimetal disk [4]. In order to use the equations for the strength of materials to handle this problem, it was necessary to set up two hypotheses (which obviously were at least partly false):

-- The disk is assumed to be thin (here, 8 mm, a negligible quantity in comparison to 40 mm);

-- The degradation is assumed uniform throughout the irradiated part, as is the mean linear contraction coefficient.

With the deformed part y(r), one finds [4]:

$$y = \frac{1}{4} \; \frac{a}{1-a} \; \frac{h1\,(h-h1)}{h^2} \; \frac{r^2}{h}$$

where y represents the deformed part, r the current point on the radius, h the thickness of the disk, and h1 the irradiated thickness.

Application of this formula to the results obtained for the energy levels 1.37 and 0.84 MeV furnishes the curve for the linear contraction coefficient as a function of the density of absorbed energy, which is given in Fig. 5.

It may be seen that as long as the accuracy of the results and calculations is sufficient, the energy of the particle becomes significant only as a function of the depth of penetration, which is a factor which can easily be computed [2] and taken into account.

Since the assumptions made for the computations were obviously false, while it was impossible to determine the extent of their inaccuracy, a more direct experiment was performed. This consisted in using a CER-VIT sample in the form of a bar 40 mm long and with a cross-sectional area of 4 mm^2. Irradiation with electrons of 1.37 MeV supplied a dose distribution which, although not uniform, did cover the entire sample. The linear contraction was obtained directly for a flux of $2 \cdot 10^{15}$ e^-/cm^2.

Measurement yielded a coefficient:

$$a = 3.5 \cdot 10^{-4}$$

while the preceding calculations had predicted:

$$a = 1.5 \cdot 10^{-4}.$$

The order of magnitude was thus found to be the same (which is satisfactory for computation of the strength of materials and with the assumptions made in this case).

2.3. Irradiation of CER-VIT Mount 40 cm in Diameter

On the basis of the preceding results, it was possible to determine the irradiation parameters (energy and flux level) for irradiation of the complete device.

The shape of the mirror mount reserved for this purpose was not the same as that finally used. The outer and inner circumference of the mount was stiffened by two skirts 10 mm thick and 30 mm high. This structure was highly resistant to deformation: using the terms for strength of materials with reference to a thermocouple embedded at its periphery, it may be seen that the simultaneous production of deformation due to contraction and deformation due to the moment produced by the embedding yields a zero result as long as the embedding prevails, even though significant internal stresses are developed as a consequence.

On the other hand, it is extremely difficult to quantify this qualitative analysis, that is, to assess the extent to which stiffness may be obtained by embedding.

Measurements of the possible degradation were performed by recording a foucaultgram of the surface with its coating (Photograph 2, Ref. [6]).

No deformation was observed, even for the maximum flux of $5 \cdot 10^{14}$ e^- with 1.37 MeV per square centimeter.

However, a new problem resulted from this irradiation. It appears that, to the extent that the presence of metallization permits an assessment of this phenomenon, the darkening of this mirror may be less significant than that observed in the control samples during the same irradiation. This raises the question of the reproducibility of the behavior of the material as a function of the casting processes it has undergone. However, we have had neither a confirmation nor a denial of this coloration, since to our knowledge the requestor has not yet proceeded with demetallization of the mirror.

Even if the deformation of the mirror is not significant, due /

to its structure, the existence of a high contraction coefficient in response to irradiation will produce stresses within the material. Further research is therefore under way to test other materials such as Verodur (whose behavior appears to be very similar) and silica.

The physical interpretation which we will suggest, for lack of any proven explanation, is the so-called "sandpile" explanation: that is, that the effect of the radiation is to decrease the gaps present in these vitreous structures, in the same as one may decrease the volume of a pile of sand by vibrating it. We were led to this interpretation by the behavior of vitreous or crystallized silica in response to neutron irradiation [3].

This study has led to the following conclusions:

-- First, that the risk of degradation by irradiation does exist, even for a material initially believed to be relatively solid and functioning only for support;

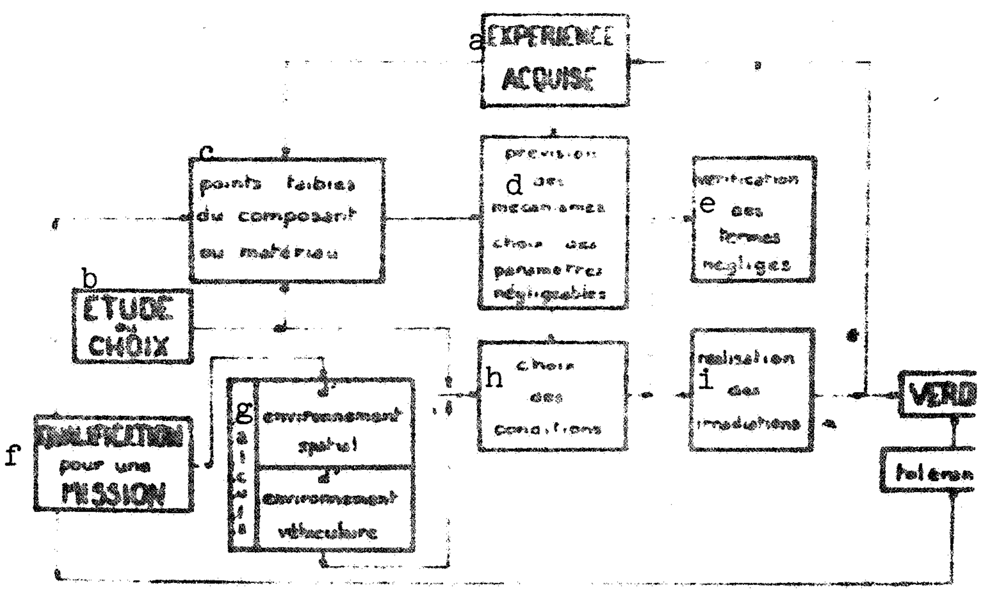
-- That the problem of simulation is a complex one; this, of course, is because the phenomena themselves are complex, but especially because there have been no previous experiments in this area.

On the basis of these observations, satisfactory qualification of a material or component may be considered to include the following steps:

-- A general preliminary study of the material or component conducted experimentally or on the basis of previously acquired information; the initial purpose of this study would be to assess the influence of the various parameters and to subject the material or component to a more or less complex irradiation representing adaptation to a "standard mission"; in addition this study would permit comparison with other components of the same type, making it possible to choose among them; this is the "test" or "choice" irradiation;

-- Second, when this material or component has been chosen for a specific mission, if the preceding study has not been sufficient, due to the order of magnitude, the dose, too limited a sensitivity, the nature of the structure assigned to a component composed of a material which has already been studied, or any other reasons, an irradiation may be performed using more accurately computed parameters; this will be the actual "qualifying" irradiation.

TABLE 1



Key: a. Acquired experience.
b. Test or choice.
c. Weak points of material or component.
d. Prediction of mechanism; choice of negligible parameters.
e. Checking of overlooked terms.
f. Qualification for a mission.

[Continued on following page.]

g. Calculations: space environment; environment within vehicle.
h. Choice of conditions.
i. Production of irradiation.

TABLE 2

Energy (MeV)	Depth of Coloration (mm)	Computed Depth (mm)	Electron Paths (mm)
0.47	0.4	0.5	0.7
0.87	1.35	1.3	1.8
1.37	2.35	2.3	3.1

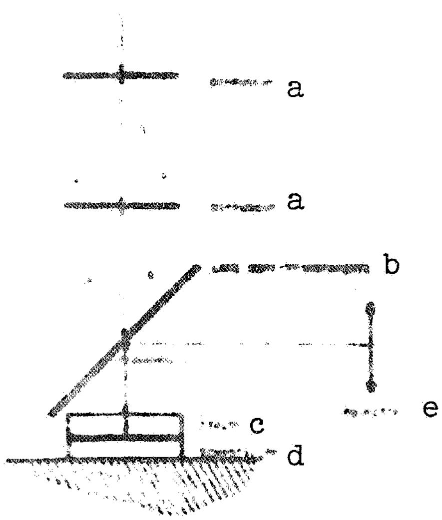


Fig. 1.

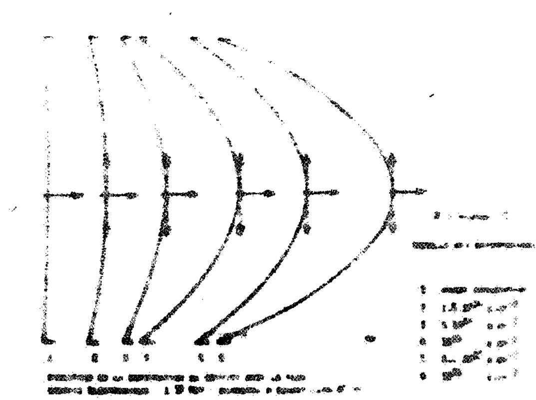


Fig. 2.

Key: a. Scatterer.
b. Semi-transparent strip.
c. Reference.
d. Sample.
e. Lens.

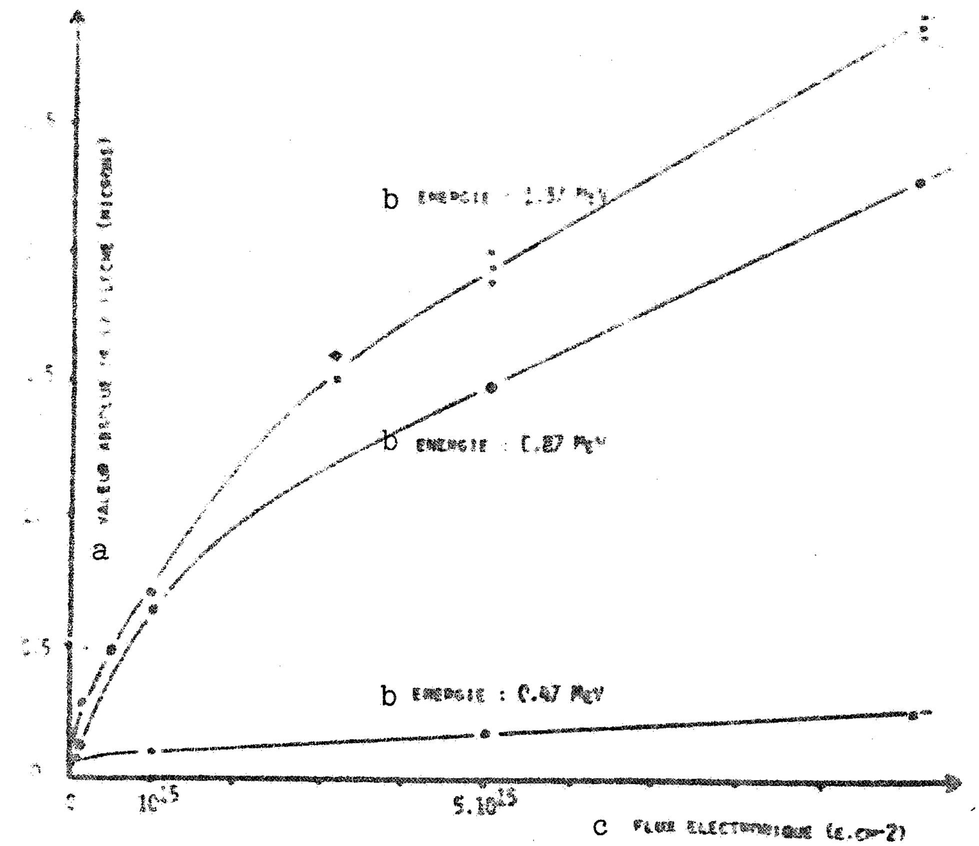


Fig. 3. Degradation curves of CER-VIT blocks (diameter = 40 mm, e = 8 mm) for several energy levels of incident electrons.

Key: a. Absolute value of deflection (microns).
b. Energy.
c. Electron flux.

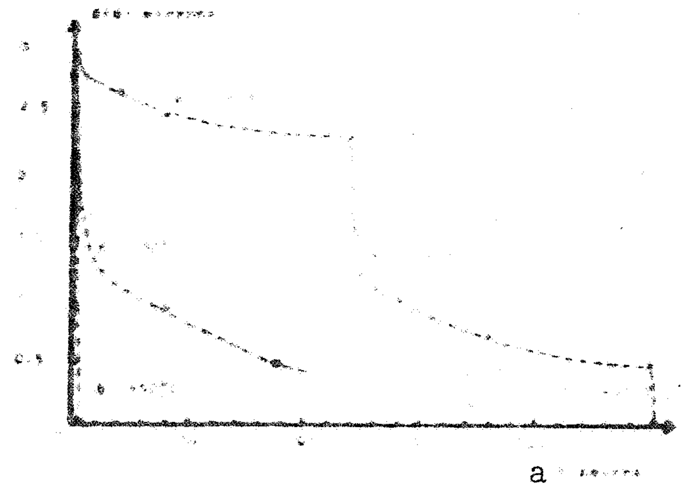


Fig. 4. Variations in maximum flux $\delta(\theta)$ with storage time
at various temperatures.

Key: a. Time in hours.

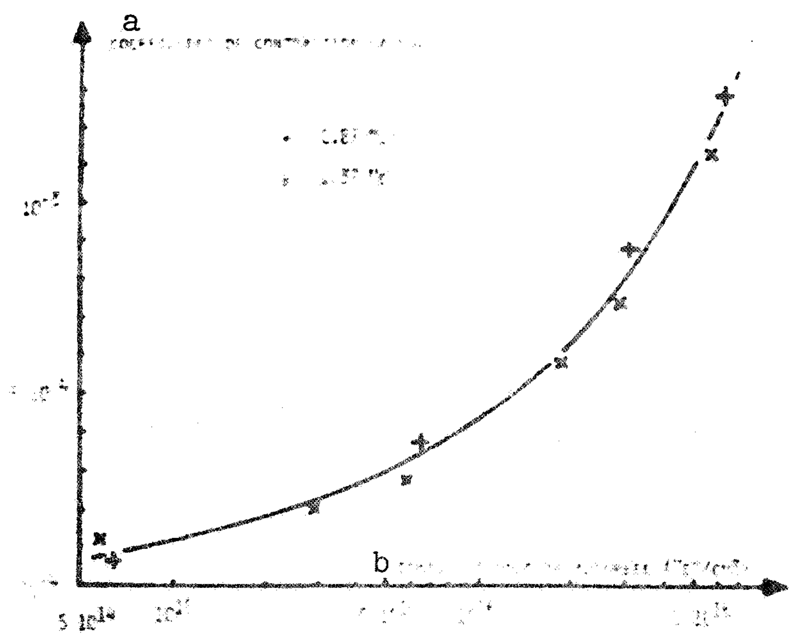
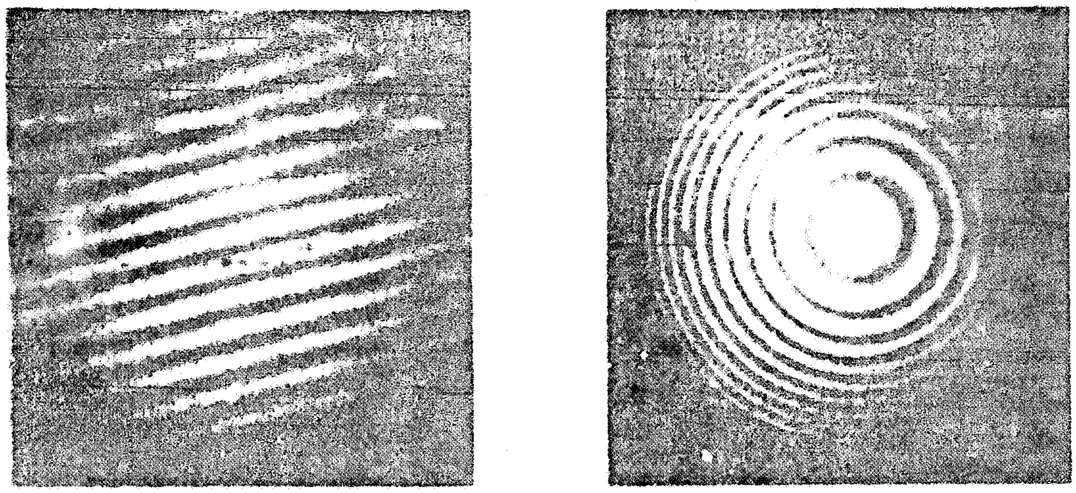


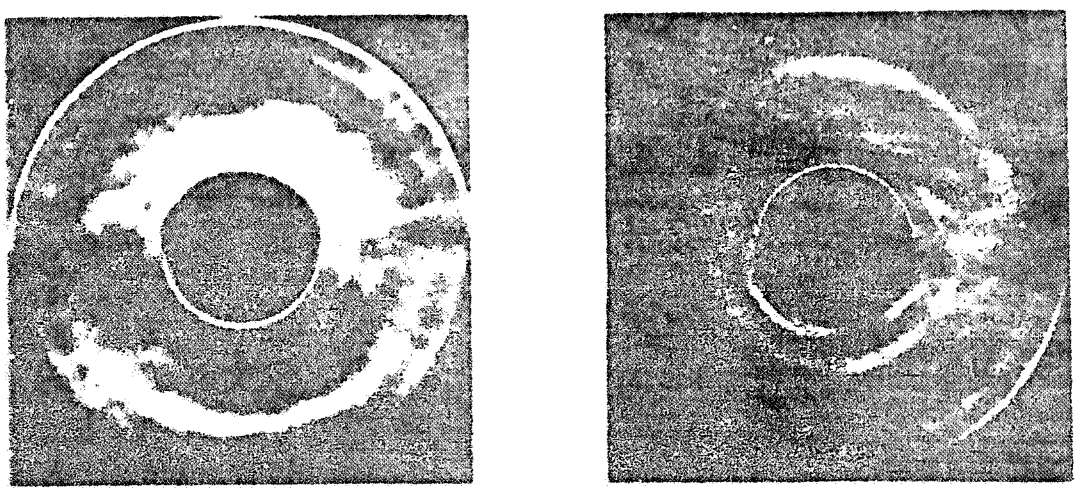
Fig. 5. Linear contraction coefficient.

Key: a. Computed contraction coefficient.
b. Density of energy absorbed.



(a) Prior to irradiation. (b) After 10^{16} e/cm^2 (energy 1.37 MeV).

Photograph 1 (a and b). Deformation of the system of fringes obtained with a CER-VIT block 40 mm in diameter and 8 mm thick.



(a) Prior to irradiation. (b) After $5 \cdot 10^{14}$ e/cm^{-2} (energy 1.37 MeV).

Photograph 2 (a and b). Foucaultgrams obtained with a CER-VIT mirror 400 mm in diameter.

REFERENCES

1. Philippon, J.-P., Doctoral Thesis No. 258, Paul Sabatier University, Toulouse, March 1970.

2. Bourrieau, J., and Schuttler, R., DERTS Publication NT/02/24 (1971).

3. Lell, Kreidl and Hensler, Progress in Ceramic Science 4, 6, Pergamon Press (1966).

4. Romero, M., DERTS Publication NP/02/14 (1973).

5. Bourrieau, J., DERTS Publication CR/02/38 (1972).

6. Bourrieau, J., DERTS Publication CR/02/55 (1973).